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PETROLEUM APPLICATIONS OF VIRTUAL REALITY TECHNOLOGY: INTRODUCING A NEW PARADIGM

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Petroleum applications of virtual reality technology: introducing a new paradigm

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SUMMARY

Many work processes in the petroleum industry go through paradigm shifts as technology improves. One such shift took place with the introduction of graphical workstations. This event led to major changes of several critical work processes within seismic interpretation and reservoir simulation over a relatively short period of time. Virtual reality (VR) technology has many potential advantages that may lead to the next paradigm shift. In this paper, we introduce a new VR-based paradigm, and summarize experiences obtained in an ongoing large-scale research project addressing petroleum applications of VR technology.

INTRODUCTION

Petroleum exploration and production (E&P) takes place in areas of increasing water depths and geological complexity. In mature areas, the undiscovered traps are expected to be smaller, more subtle, and more heterogeneous than earlier. Therefore, it will be more difficult to locate the traps, to create reliable reservoir models, and to carry out precise drilling. This development indicates that technology for efficient analysis and modelling of 3D data becomes more important than ever.

One of the most significant improvements of technology for 3D data analysis took place in the middle of the 1980s with the introduction of graphical workstations. This event led to a paradigm shift in the petroleum industry. For example, seismic interpretation could suddenly be performed on digital data instead of paper sections. Reservoir models and simulations could be presented graphically instead of using endless lists of numbers. Although further improvements can be achieved by using workstations, the most common interaction devices will always have fundamental weaknesses. For example, it is laborious and difficult to interact with 3D objects by means of a 2D mouse and keyboard. Furthermore, small flat screens make it difficult to interpret complex 3D structures. VR technology addresses these weaknesses and can lead to a new paradigm shift.

In this paper, we first describe the characteristics of a new VR-based paradigm for E&P. Then we discuss criteria for achieving general acceptance of the new paradigm, and conclude that proof-of-concept research experiments are required at this stage.

In August 1996, Norsk Hydro started planning a large-scale research project with the goal of developing value adding applications of VR technology for E&P. The project is carried out in cooperation with a group of computer scientists at Christian Michelsen Research. In October 1997, Norsk Hydro had installed an operational CAVE state-of-the-art VR laboratory. At the end of this paper, we present examples of applications of new analysis techniques for seismic data, reservoir data, and well data based upon the new paradigm.

THE NEW PARADIGM

A paradigm can be defined as a set of agreed principles for making scientific inquiries within a particular discipline at a particular period of time. Furthermore, it can be argued that science is advancing through evolution, from one paradigm to another (Kuhn 1970). One common principle, that has strongly influenced research on methods for 3D data analysis, is that interaction and display are most convenient to perform by using a mouse, a keyboard, and a flat screen. We find it natural to question this principle in view of recently developed immersive display systems, and interaction devices with real-time tracking of 3D position and direction. These types of VR technology indicate the emergence of a new paradigm that will allow geoprofessionals to:

- interpret objects, model objects, or plan production processes while being "present" in data space
- navigate through data space by use of natural body movements
- define, grab, and manipulate objects with natural arm and hand movements
- perform interdisciplinary work in a shared virtual world.

CRITERIA FOR GENERAL ACCEPTANCE

VR-technology is still in its infancy and several major limitations must be removed before it can be implemented on a broad scale in the petroleum industry. To achieve general acceptance of the new paradigm is therefore a process that must be seen in a 5 - 10 years perspective. This process relies on the following criteria:

- *Cheaper and faster computers must be developed.* Today, only the high-end graphical supercomputers can be used to run demanding VR applications. The size and cost of these machines makes it difficult to distribute VR technology to everyones desktop.
- *Lighter VR equipment must be developed.* At present, the CAVE (Cruz-Neira, 1997) seems to be the best VR technology for scientific and technical

use. Being projector-based it takes a lot of space. For that reason, implementation may be limited to a few intallations per company, making it available only to few users at the time. New compact and comfortable display technology, that provides full immersion, must be developed.

- *General user interface tools for VR systems must be developed.* One important reason for the wide acceptance of the workstation paradigm is the emergence of interactive tools for creating mouse and button driven user interfaces. Similar tools are not yet commercially available for new kinds of tracked VR devices.
- *Commercial software must be developed.* To our knowledge, there is no commercially available tracked VR system developed specifically for E&P.

It follows from the above that the new paradigm cannot be fully established without a massive research effort from the E&P industry and the IT vendors.

At the moment, the most pressing need is to develop proof-of-concept demonstrations supporting the new paradigm. The main challenge is to show that critical operations within E&P can be performed more efficiently, with better quality, and at lower cost by using VR technology. Norsk Hydro will contribute to this process by establishing a CAVE laboratory, by developing software addressing such operations, and by sharing experiences with the petroleum industry.

THE CAVE TECHNOLOGY

The CAVE is a room (10x10x10 feet), where stereo images are projected onto three walls and the floor by means of high precision projectors (Figure 1). All users wear shutter glasses, which are synchronized with the stereo images displayed by the projectors for the left and the right eye in rapid succession. Stereo viewing in combination with full field of view gives the users a very special feeling of being "present" in data space (i.e. to experience immersion). The main user's shutter glasses and 6D mouse (Wand) are tracked in the CAVE by means of an electromagnetic positioning system. This technology makes it possible to navigate and interact with data by means of natural body movements. The CAVE is also equipped with a sound system that can be used as part of the user interface.

We chose to base our VR laboratory on a CAVE because this technology offers:

- full immersion
- independent real-time tracking of head and hand movements
- an ideal enviroment for interdisciplinary work and data integration (6-8 persons can be present in the CAVE at the same time)

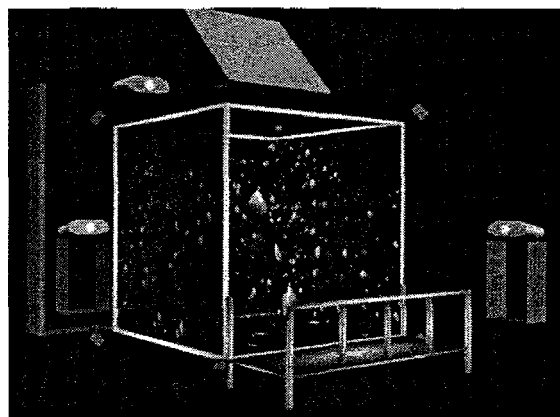The CAVE technology and other alternatives are described in more detail by Cruz-Neira (1997).

Figure 1 The CAVE structure and the projectors

EXAMPLES OF VR-FUNCTIONALITY FOR E&P

A software system for integrated analysis of different types of 3D petroleum data is currently being developed. For a technical description of the system, see Giertsen and Midttun (1998). At the moment, the system incorporates software developed at the National Center for Supercomputing Applications in the United States (Brady *et al.* 1995).

The system aims at improving the quality and the efficiency of seismic interpretation, reservoir modelling and well planning. The users perform analysis and modelling in the system by means of socalled VR-tools, that operate on specific types of data. The VR-tools can be used separately or in combination. In this section, we describe examples of VR-tools and their applications. The figures included in this section gives an indication of the functionality of some of these VR-tools, but do not give any hint on what it means to experience immersion. The figures have been generated using the CAVE Simulator, which is a useful software development tool running on ordinary workstations.

Seismic data

At present, the system includes four different VR-tools for analysing 3D seismic data in the CAVE. The point cloud tool and the full volume tool aim at giving the users increased global understanding of the dataset e.g. the positions of the main reflectors and faults. With the point cloud tool, only the samples within a specific amplitude range are plotted, e.g. high amplitudes. With the full volume tool, the entire data set can be shown semitransparently, but resampled to lower resolutions if the size prohibits real-time rendering.

More detailed analysis can be performed using the slice tool or the volume window tool. In both cases, a scalable window is placed at the tip of the Wand. The window can be moved and twisted in any direction through the data cube by moving the Wand. At the same time, the seismic data within the window will be displayed in real

time. A window can be dropped at any location in the volume and new windows can be activated and dropped in the same way. The slice tool displays one opaque plane, while the volume window tool displays a semitransparent subcube.
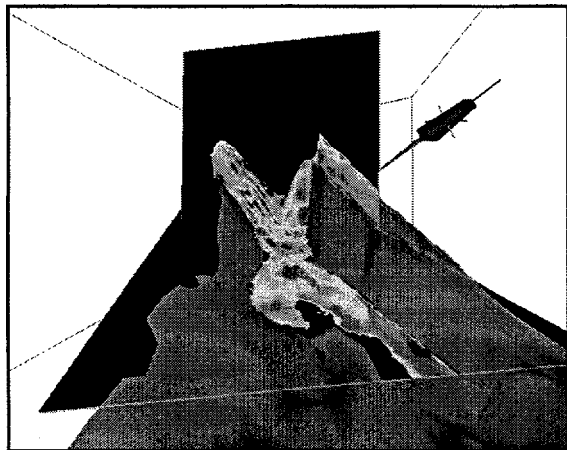

Figure 2   An interpreted surface and two slice planes.

The slice tool is illustrated in Figure 2. The seismic data shown in this figure consist of acoustic impdance values from a North Sea reservoir. Two slices have been generated, one nearly perpendicular to the other. Also shown on the figure is a surface imported to the CAVE system and displayed using another VR-tool, called the surface tool.
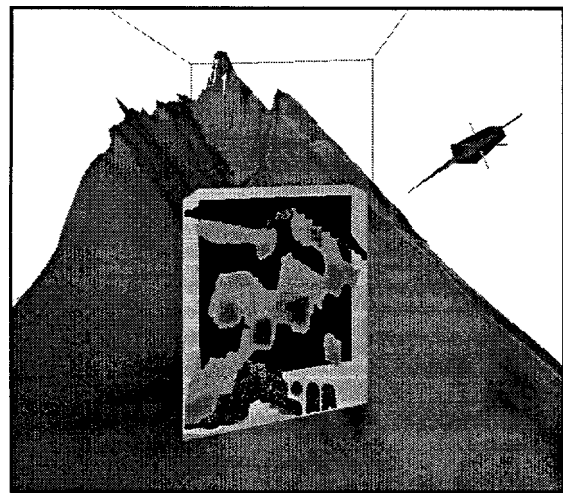

Figure 3   An interpreted surface and one volume window.

The volume window tool is illustrated in Figure 3. The window is located in a part of the reservoir that is expected to contain channel sands. The high impedance values have been made transparent. As seen on the figure, the remaining low impedance values define three objects formed like channels.

It is our experience that these VR-tools can lead to faster and better geological understanding of seismic data sets. The feeling of being physically present inside the datacube and looking at geologic objects from different angles by means of natural body movemens is clearly a valuable contribution to improving seismic interpretation. The combination of seeing seismic data and interpreted surfaces, in stereo at full field of view in the CAVE, makes it possible to study details in the dataset while at the same time keeping a global overview.

Well data

Well planning is a typical interdisciplinary work task involving integration of several data types and collaboration between a wide range of professionals. Furthermore, horisontal and multibranch wells have increased the demands for accurate positioning. Well planning is therefore a time consuming process involving several iterations between expert groups using different software systems. Traditionally, the position of a new well is decided based upon 2D map displays and crossections as well as technical drilling considerations. The CAVE-technology, where 6-8 persons easily can share experiences in a virtual world, has a potential for improving the well planning process.

Well data is handled by the path tool. This tool is designed for visualizing existing well paths and logs, and for planning and steering new wells. Figure 4 shows an example of applications of the path tool in the same area as the previous figures. The tool is shown in combination with the surface tool and the volume window tool. The thick lines at the back of the figure are well paths for existing wells in the area that have been selected and imported from a well database. Different well logs can be selected and plotted along the well paths. In Figure 4, gamma ray log values are displayed color coded along the well paths. Visualisation of borehole imaging logs is currently being implemented.

Interactive drawing of new well paths is also possible in the current version of the path tool. This is done by clicking the Wand at different positions in 3D space, creating a node point at each click. A spline curve representing the well path is automatically drawn between the node points. The position of the well path may be guided with one of the seismic tools. In Figure 4, a horizontal well path has been placed in the middle of the rightmost channel body. The well path is shown as a thin line coming out of the front of the channel and bending off towards the upper surface. One of the node points can be seen as a small cube in the upper left of the figure. The length of the new well can be computed and the node points can be exported and used by other software systems in the planning process.

This example demonstrates that new well paths can be placed in real time in 3D space in an accurate and efficient manner. The planned well paths can be directly

checked against seismic data, existing well data, and reservoir models, while all "owners" of the different data are present in the CAVE. We strongly believe that well planning in VR will lead to more optimal well positions than conventional technology. By including real-time registrations from MWD/LWD/SWD we further believe the CAVE can be used actively as a geosteering tool during the drilling process. This possibility will be further looked into in the continuation of the project.
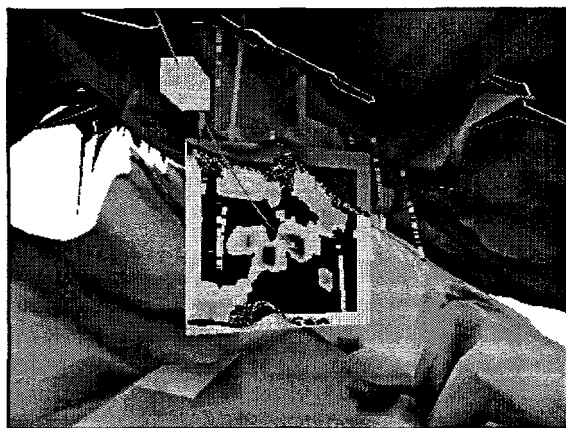

Figure 4   Two interpreted surfaces, a volume window, some existing wells, and a new well being planned.

Reservoir data
Reservoir models are increasing in size and complexity. As a result, the visualisation and the quality control of the models and the reservoir simulation results are becoming more difficult and time consuming.
Reservoir models and simulation results can be analysed in the CAVE by use of the irregular index tool. Parts of the grid can be selected interactively either by choosing cell index intervals, or by specifying parameter ranges for the cells to be displayed. Parameter values for individual cells can be changed. Areas containing errors or artifacts can be marked for later adjustment in a modelling or simulation program. We plan to extend this VR-tool by including functionality for showing animations of simulated reservoir parameters over time.
Figure 5 shows an example of application of the irregular index tool. We see a part of a reservoir model from the same area as shown earlier. Only those cells containing channel sands have been selected, resulting in a pattern of twisted sandbodies. The model can be analysed very efficiently in the CAVE. A three-dimensional understanding of the model is obtained immedeately. The shape of individual sandbodies and the connection between different channels can be studied in detail in an intuitive manner. In this particular example, lack of continuity in some of the modelled channels was dicovered that had not been seen earlier on a graphical workstation. Also, improved understanding of the distribution of channel sands in space was achieved.

Results from reservoir simulations, such as the distribution of remaining oil, can be analysed in the same manner by the irregular index tool.
Based on our experience with the prototype version of the irregular index tool we conclude that reservoir models can be analysed more efficiently and with higher quality in the CAVE than with workstations.
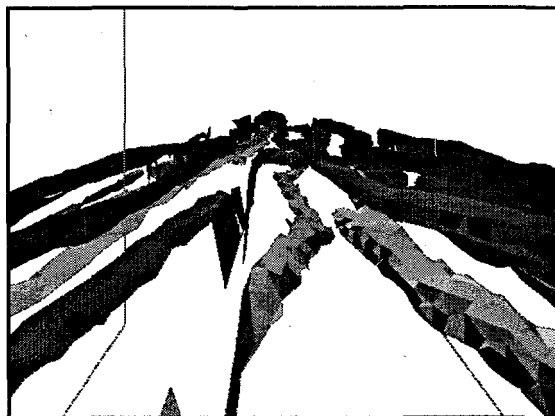

Figure 5   Channel structures in a reservoir model.

CONCLUSION
We have introduced a new paradigm and presented examples of VR-functionality for E&P based upon this paradigm. Our pilot applications clearly support the claim that VR-technology has the potential of improving the efficiency and the quality of several critical work processes in E&P. However, much more research is needed in order to quantify possible cost savings and other advantages of this approach. This is necessary in order to achieve general acceptance of the new paradigm.

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